

# Matsu: An Elastic Cloud Connected to a SensorWeb for Disaster Response

(Session 12F Working Group: **Cloud Computing for Spacecraft Operations**)

Daniel Mandl - NASA/GSFC

3/2/11

## Ground System Architectures Workshop

**"Harmonization: Challenges and Opportunities"**

Sheraton Gateway Hotel, Los Angeles

February 28–March 3, 2011



# SensorWeb High Level Architecture

floods, fires, volcanoes etc



**GeoBPMS**

**Data Processing Node**

SensorML Capabilities Documents

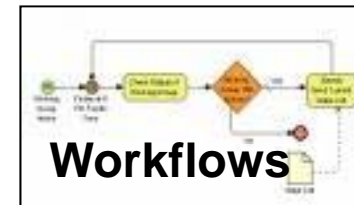
Web Coordinate Transformation Service (WCTS)    Web Processing Service (WPS)    Web Coverage Service (WCS)

**RSS Feeds**

**Internet**

**OpenID 2.0**

**Web Coverage Processing Service (WCPS)**



**SensorML Capabilities Documents**

**In-situ Sensor Data Node**

**UAV Sensor Data Node**

**Satellite sensor data product**

**Satellite Data Node**

EO-1 Satellite

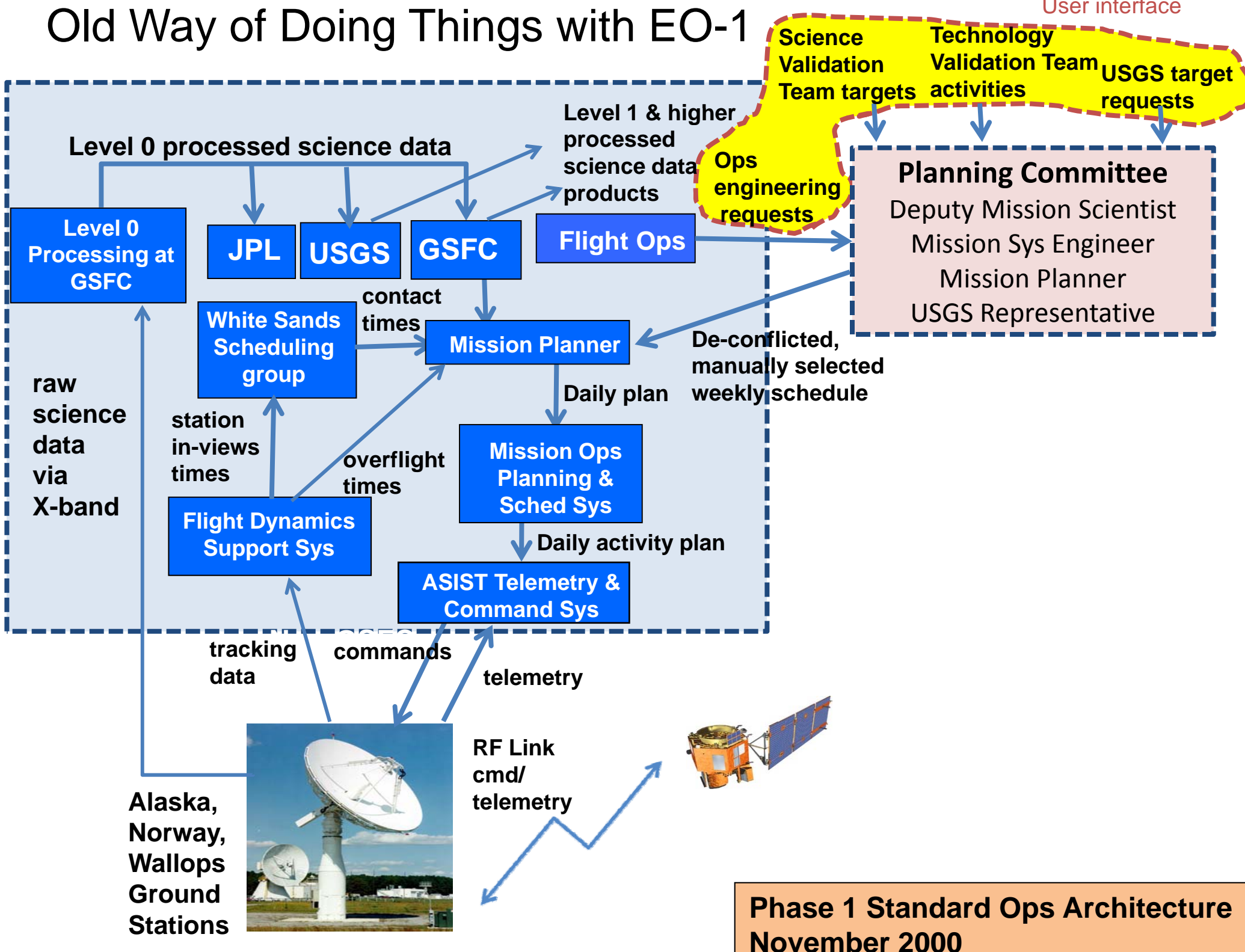
Web Feature Service (WFS)

Sensor Planning Service (SPS)

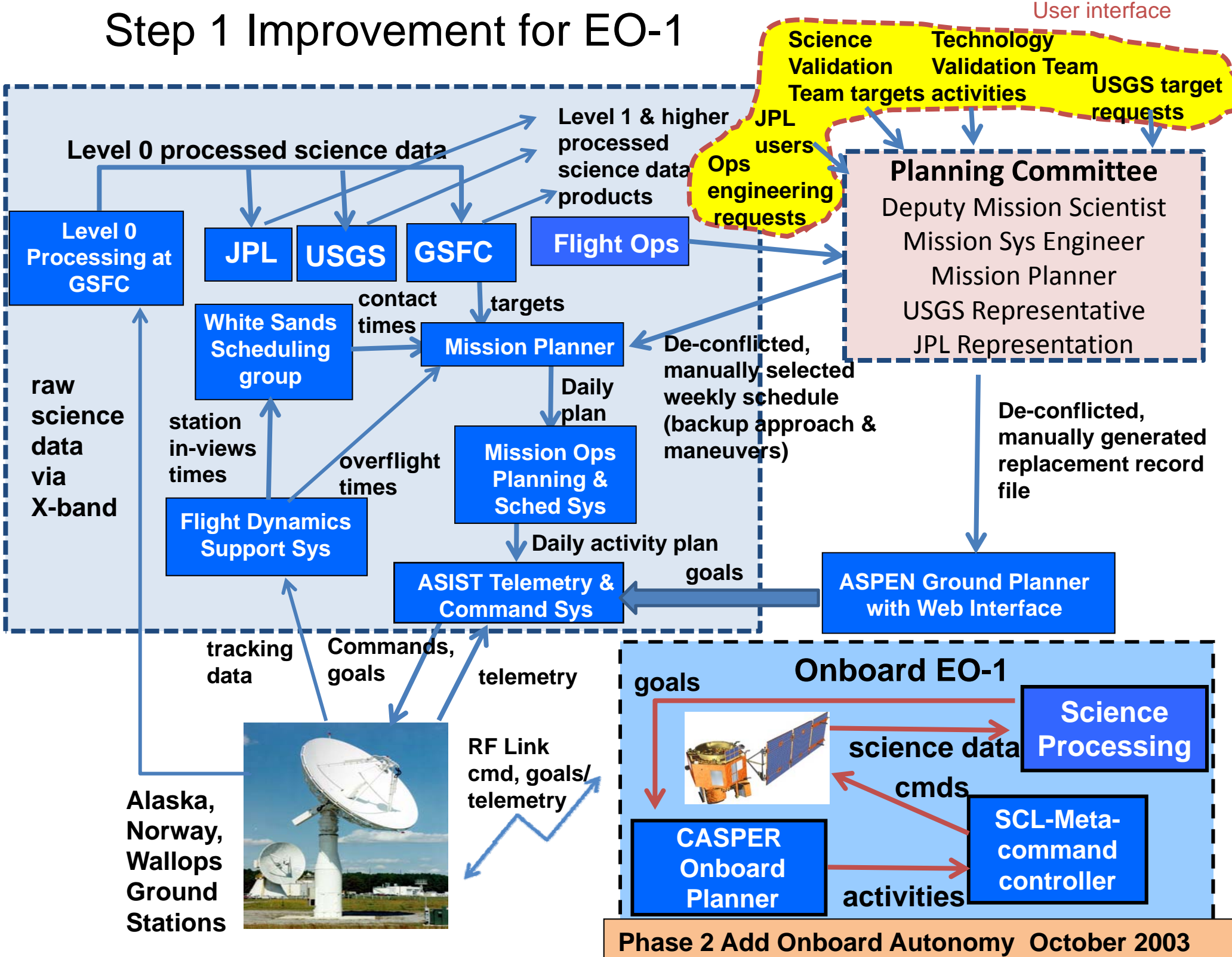
Sensor Alert Service (SAS)

Sensor Observation Service (SOS)

# Old Way of Doing Things with EO-1

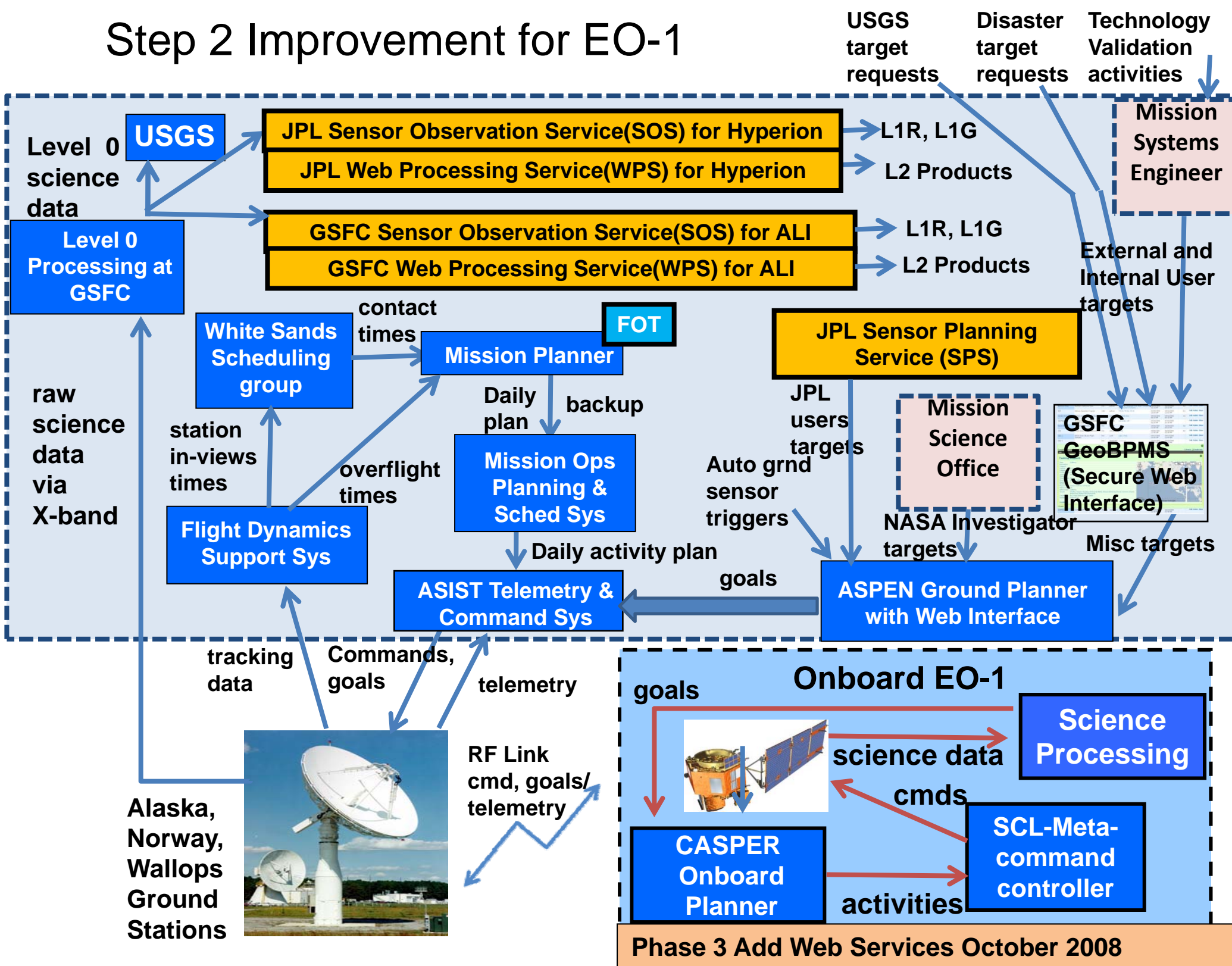


# Step 1 Improvement for EO-1



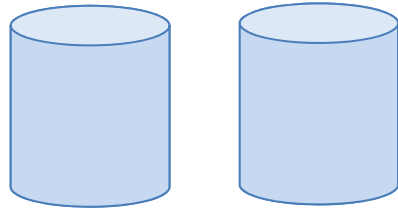


# Step 2 Improvement for EO-1

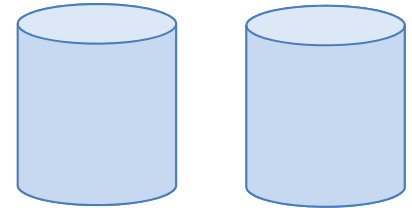




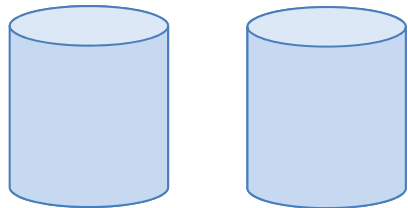
# Open Science Data Cloud



Biological data  
(Bionimbus)



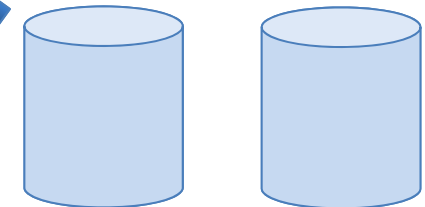
Astronomical data



Earth science data (& disaster relief)

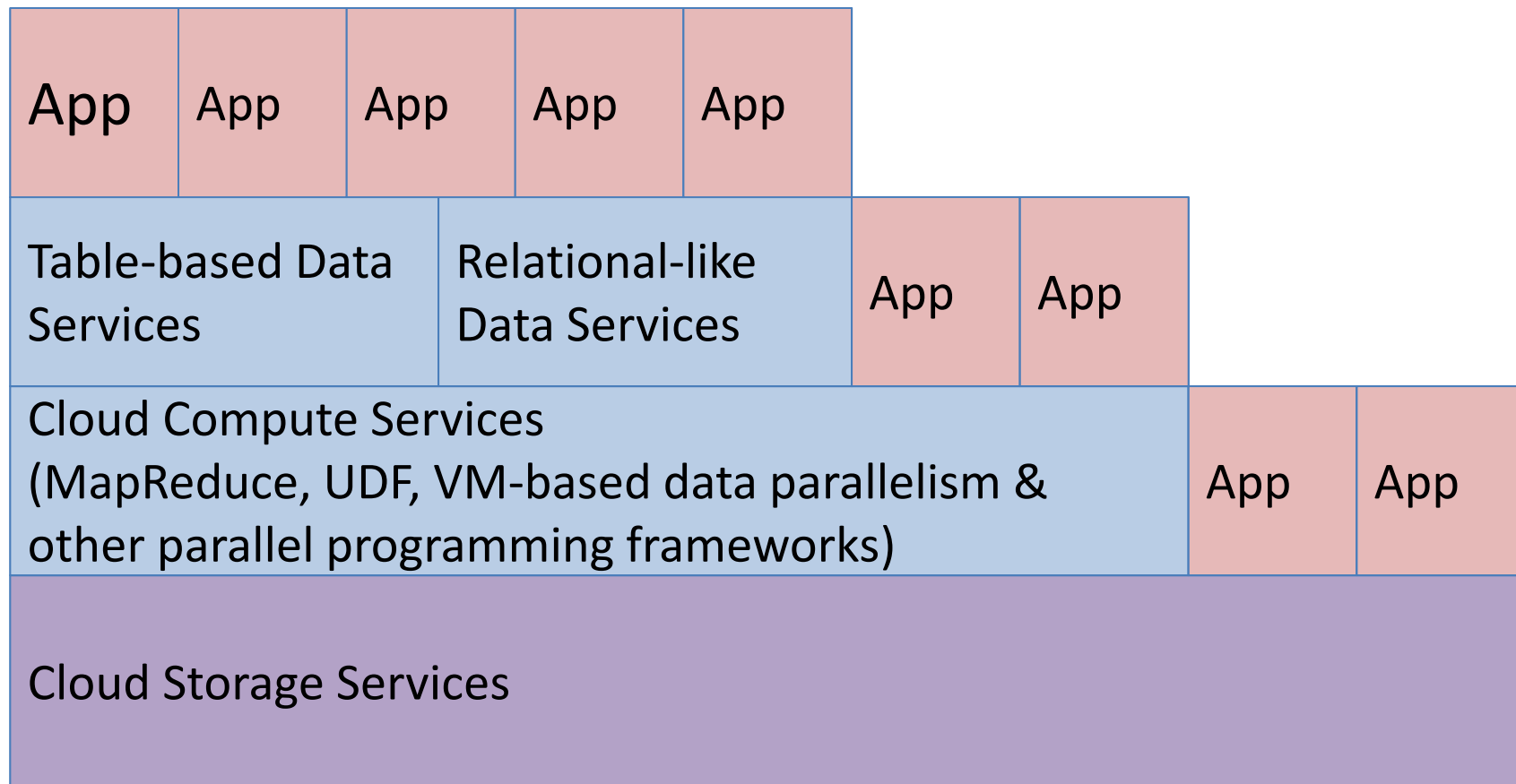


**UIC**



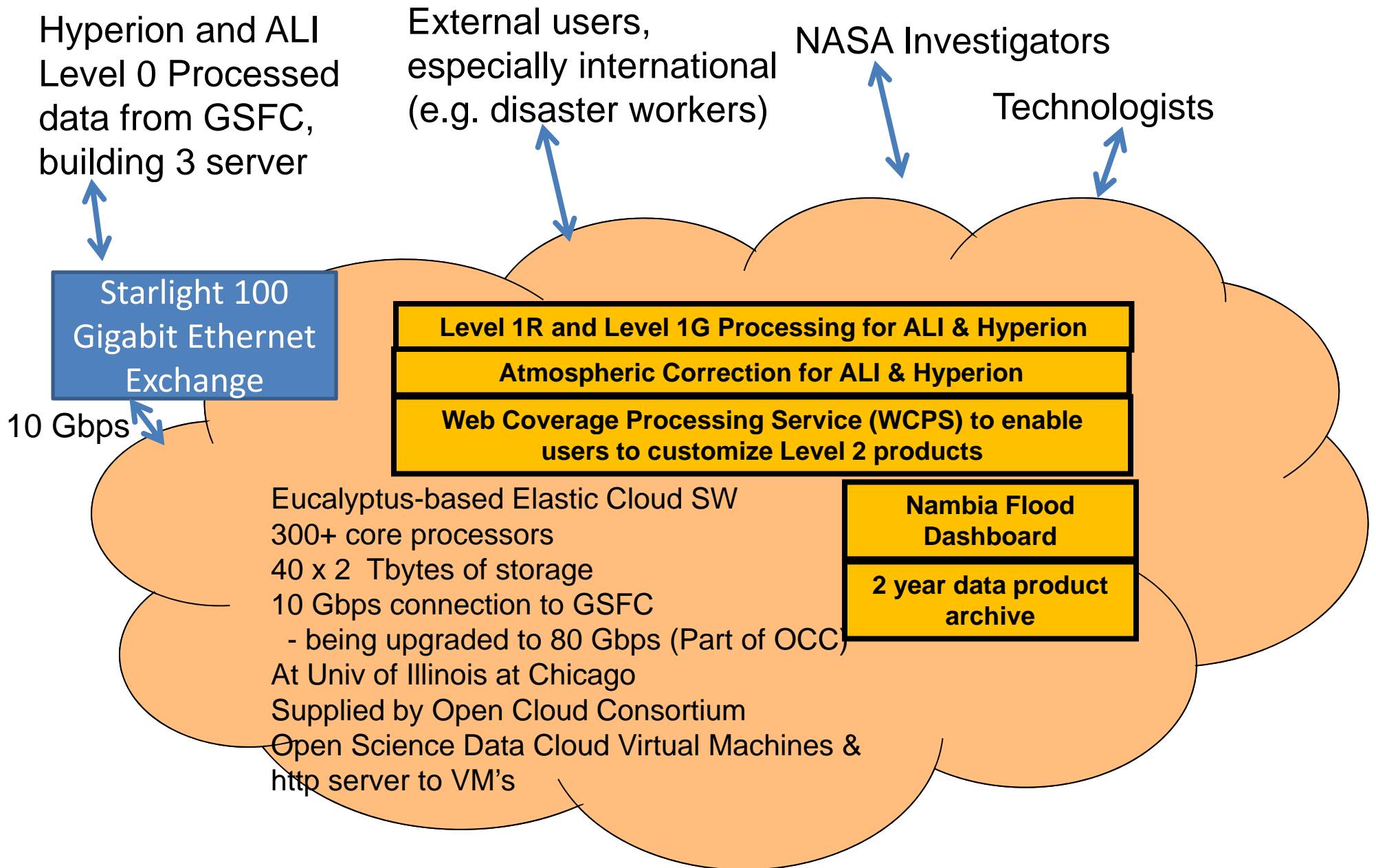
NSF-PIRE OSDC Data Challenge

# Focus of OCC Large Data Cloud Working Group



- Developing APIs for this framework.

# Step 3 Improvement for EO-1 - Overview



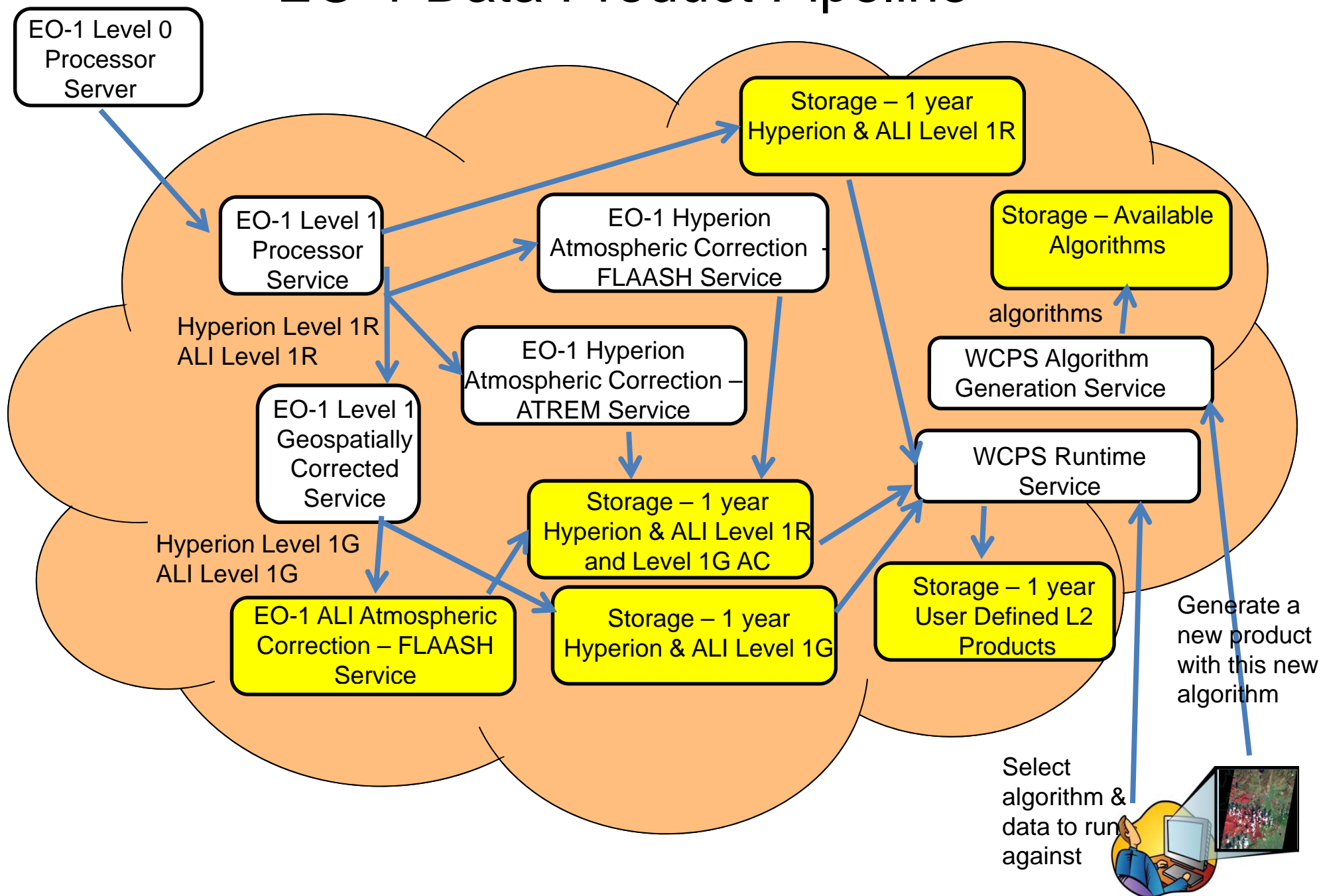
OCC = Open Cloud Consortium

Phase 3 Add Elastic Cloud Ongoing Feb 2011



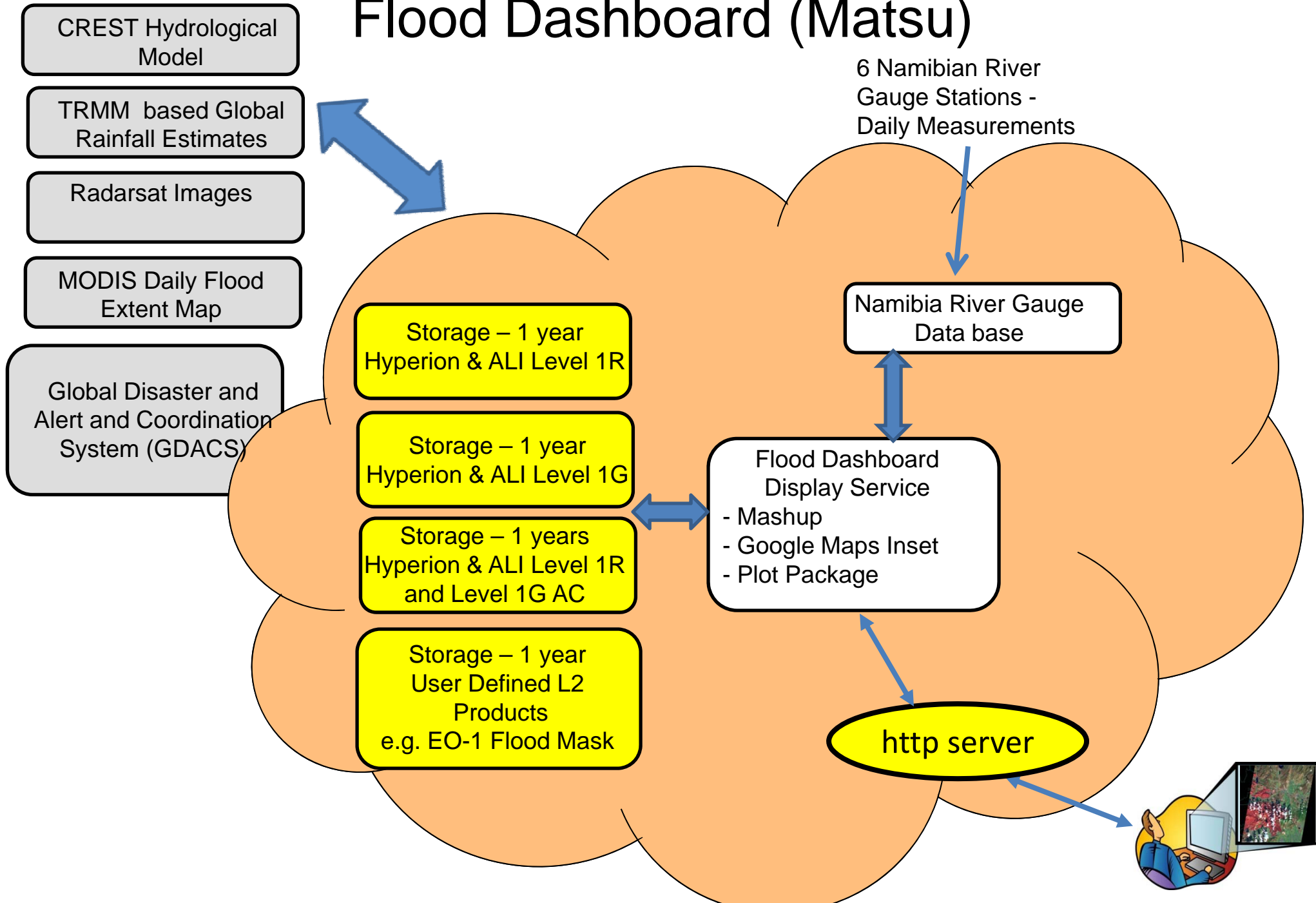
# Transformation to On-Demand Product Cloud Part 1

## EO-1 Data Product Pipeline



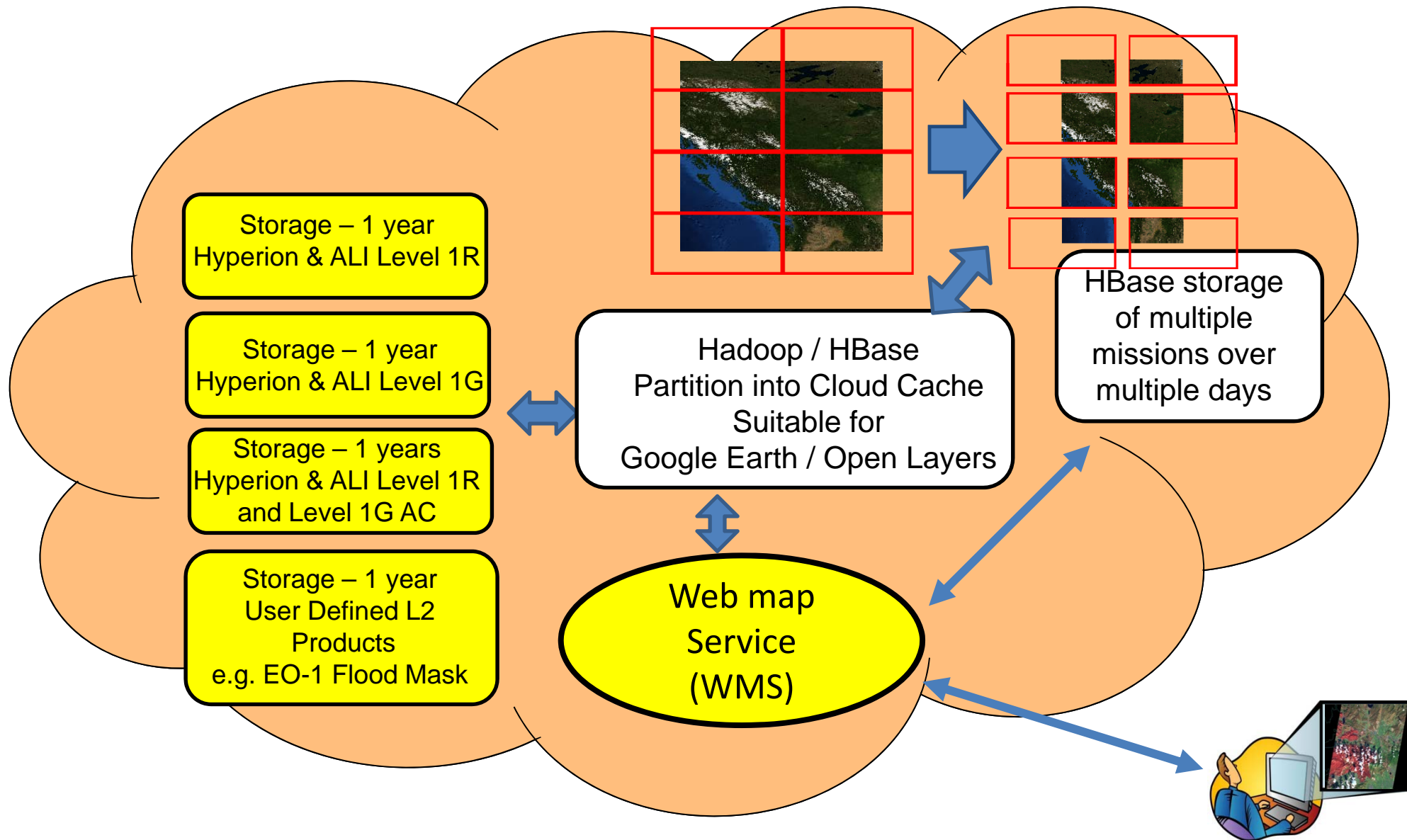
# On-Demand Product Cloud Part 2

## Flood Dashboard (Matsu)



Phase 3 Add Elastic Cloud Ongoing Feb 2011

# Detail of Processing Image Data in OCC Open Science Data Cloud



# Top Level Flood SensorWeb Concept

Manual or automated triggered requests for satellite imagery in area of interest

Customized plan of needed satellite images

SPS



SPS



SPS

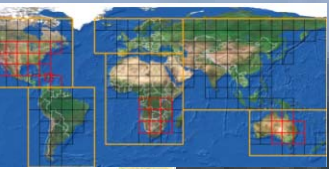


Flood conditions

Compare to history

\*SPS = Sensor Planning Service

Improved flood prediction model

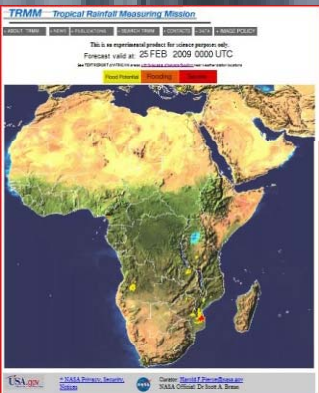


**GeoBPMS – Web based satellite tasking tool**

Agency	Program	Lat	Lon	SR	SR	SR	SR	SR	SR
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100
USA	Advanced Earth Observing Program	100	100	100	100	100	100	100	100

Flood alerts to users

Ground flood measurements to validate model



**Global Flood Detection System**

Statistics for Site 71 (page 1 of 6)

Signal (8 day average) (MTC)

Flood signal 4-23-2009 for Site 71

Flood signal 4-23-2009 for Site 7

Map of the region showing Site 71 and Site 7.



# Portion of 2011 Namibian Flood SensorWeb Early Warning Pilot

Angola



Namibia

**Shanalumono  
River Gauge Station**



**Water flow from  
North through basin**



**Oshakati**

**Ongwediva**



TRMM based rain estimates= Monitor rains upper basin

Early user alert

Global Disaster and Coordination System- (Based on AMSR-E)

Shanalumono River Gauge Station

GeoBPMS

MODIS Daily Flood Mask

Follow flood wave down basin

Auto triggers

Auto-trigger Hi-res Satellite images

Daily flood gauge levels & predicted river levels plots

Flood Dashboard (mashup)

High resolution satellite imagery (e.g. EO-1)

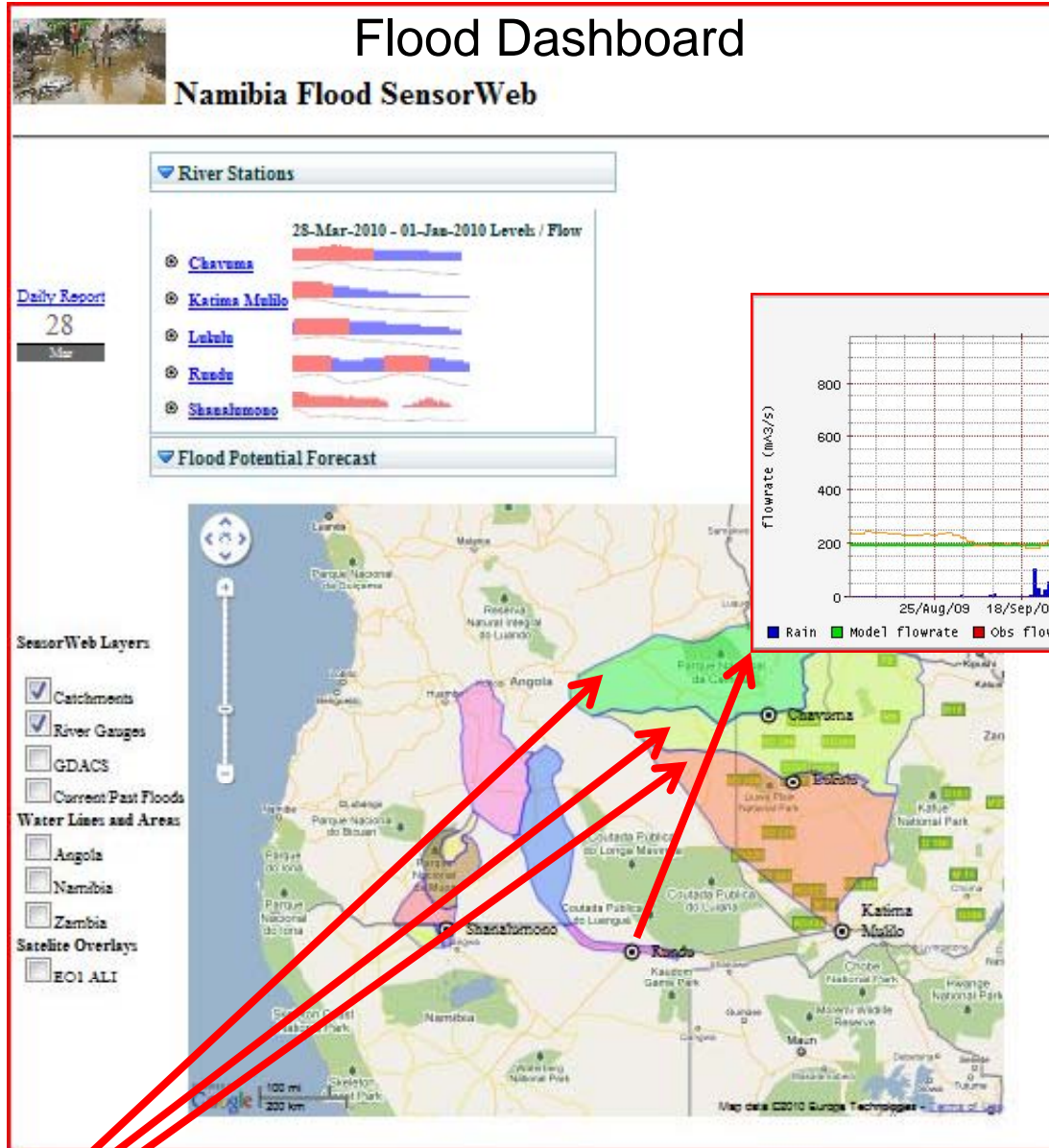
Oshakati

Ongwediva

Portion of 2011 Namibia Flood SensorWeb Early Warning Pilot:

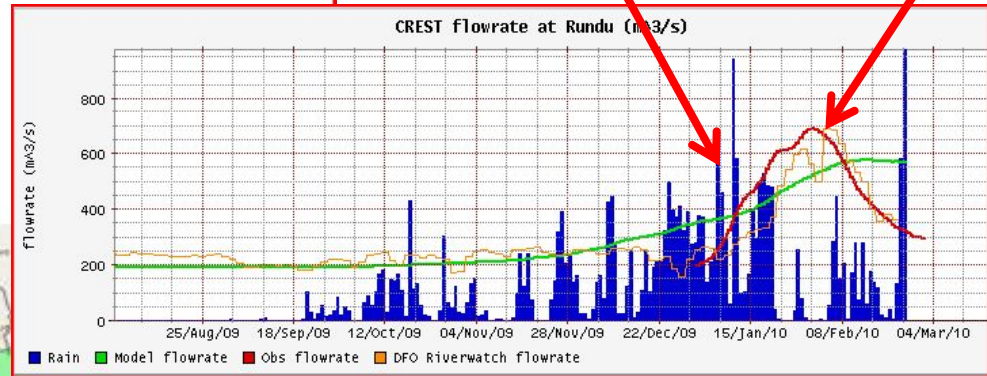


# Experimental Namibian Flood SensorWeb Webpage



Note blue bars indicating a surge of rainfall upstream

Then a flood wave appears downstream at Rundu river gauge days later



## Namibia Short Term Pilot for 2010

- Colored areas represent catchments where rainfall collects and drains to river basins
- River gauges displayed as small circles
- Detailed measurements are available on the display by clicking on the river gauge stations.
- This display can be viewed and manipulated at:

Zambezi basin consisting of upper, middle and lower catchments

<http://geobpms.geobliki.com/namibia>  
and  
<http://geobpms.geobliki.com/namibia2>



# Shanalumono River Gauge Station and Part of Community Prone to Flooding Downstream



# Experimental Namibian Flood SensorWeb Webpage View of Available Envisat & EO-1 Overlay Images

## Flood Dashboard

### Namibia Flood SensorWeb

Experimental TRMM-based Flood Forecast Products

River Stations

Flood Potential Forecast

[1-Day Flood Potential Forecast](#)  
[5-Day Flood Potential Forecast](#)  
[Severe Flood Report](#)

[Daily Report](#)  
25  
Apr

Envisat SAR and EO-1 Optical Image Overlays

**SensorWeb Layers**

- Catchments
- River Gauges
- GDACS
- Current/Past Floods

**Water Lines and Areas**

- Angola
- Namibia
- Zambia

**Dwelling Density**

- Northern Namibia

**Satellite Overlays**

- EO1 ALI
- SAR (SRI/Ukraine)

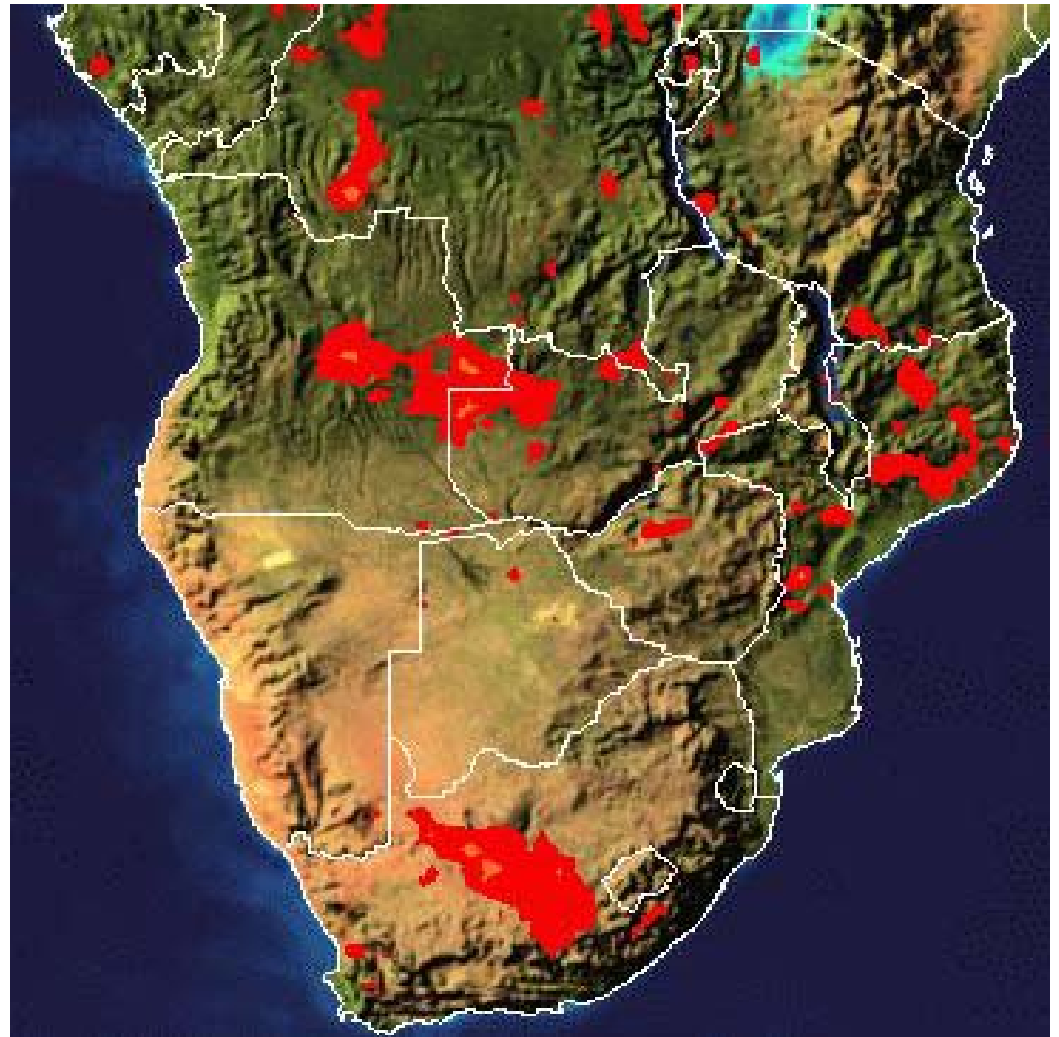
**2010-01-30 Flood Water Area**  
Flood/water mask derived from SAR imagery  
Image credit: Copyright ESA 2009, 2010  
Image processing, map created by:  
Space Research Institute,  
National Academy of Sciences of Ukraine,  
National Space Agency of Ukraine.

2010-03-28 (07:58 UTC)  
[Download KML file](#)



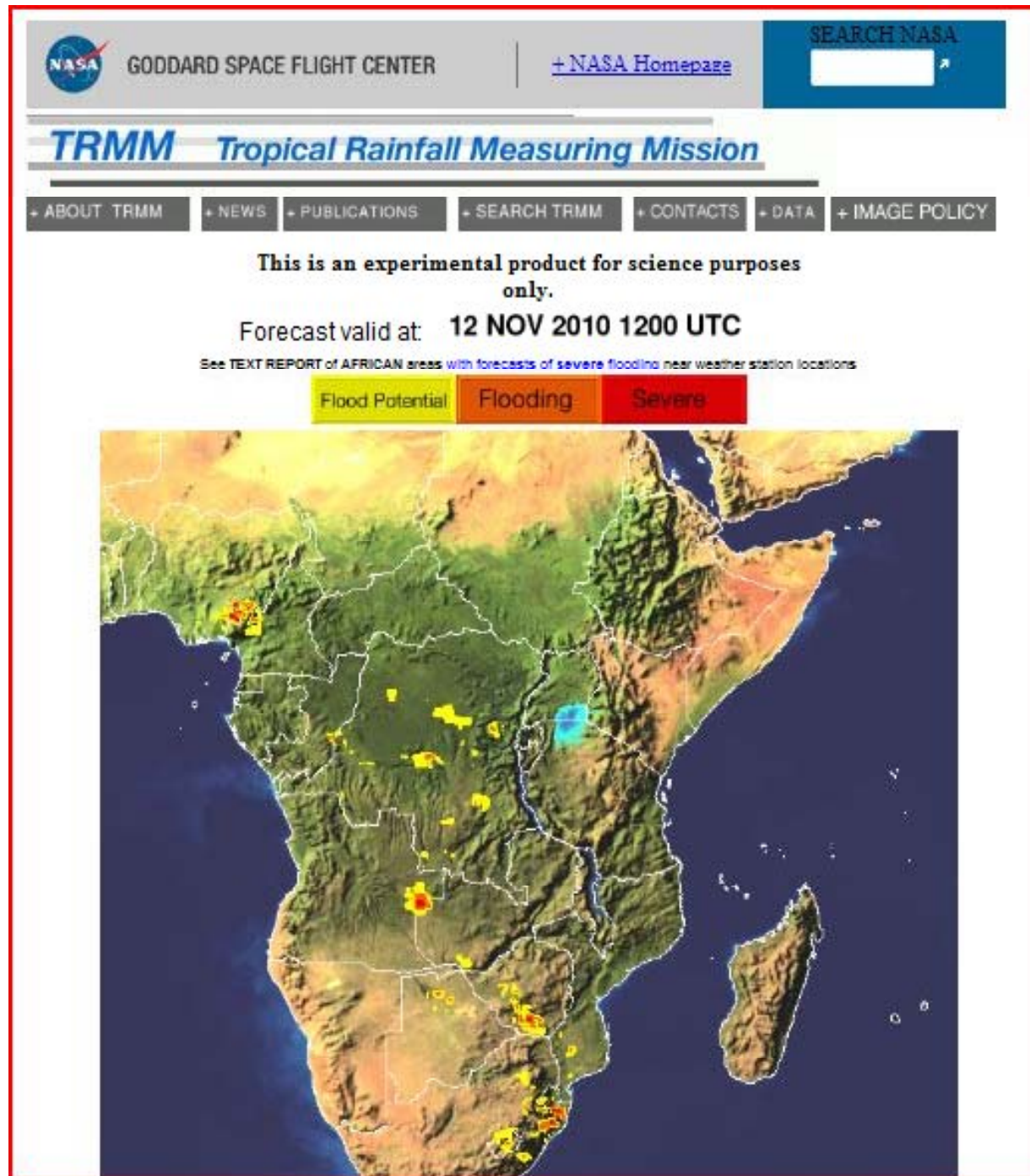
# Estimated Rainfall Webpage Based on TRMM Data

- Experimented with various hydrometeorological information for flood forecasting models
  - remote sensing
  - rainfall estimates
  - 24 February 2010
  - NASA Servir Africa
  - red is  $> 35$  mm

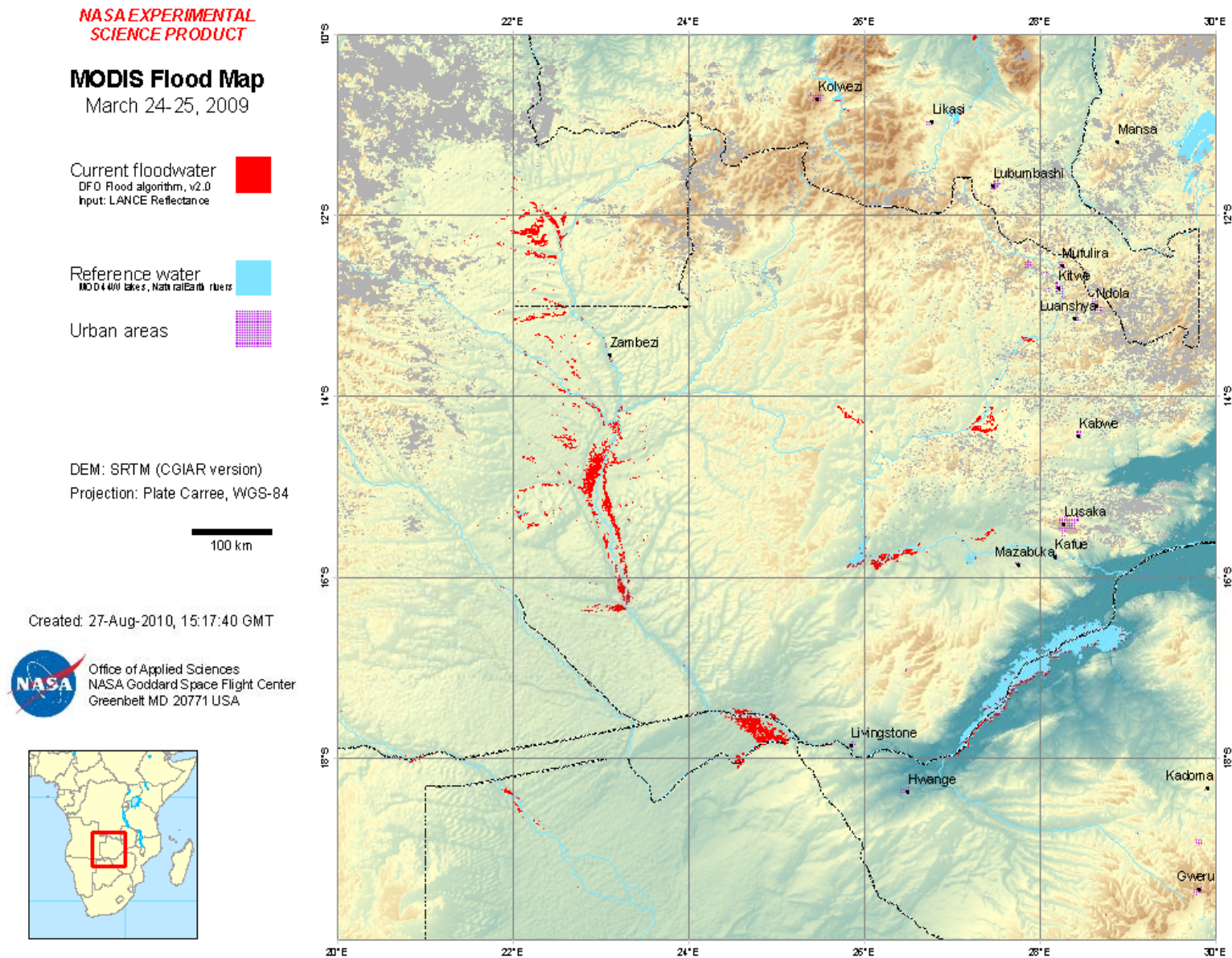




# Experimental Global TRMM Based Flood Forecast



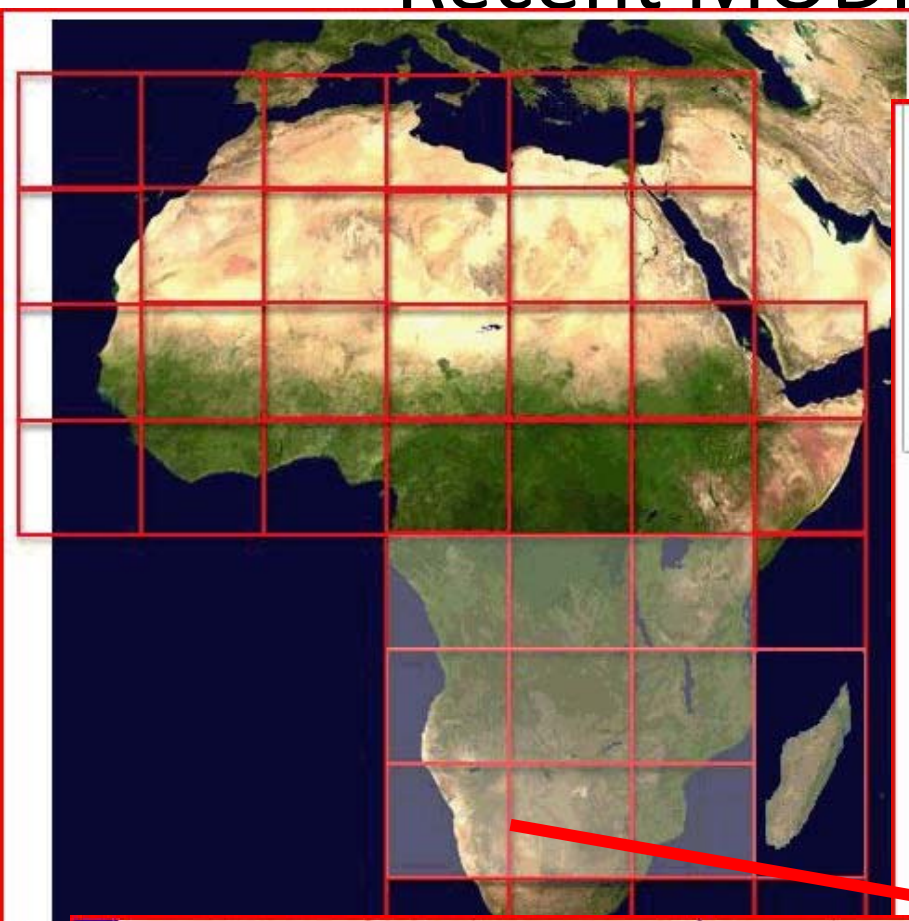
# Experimental Flood Extent Data Product Derived from MODIS



First product out of automated MODIS flood extent map pipeline prototype. Used data from March 2009 when large floods occurred to test.



# Recent MODIS Daily Flood Extent



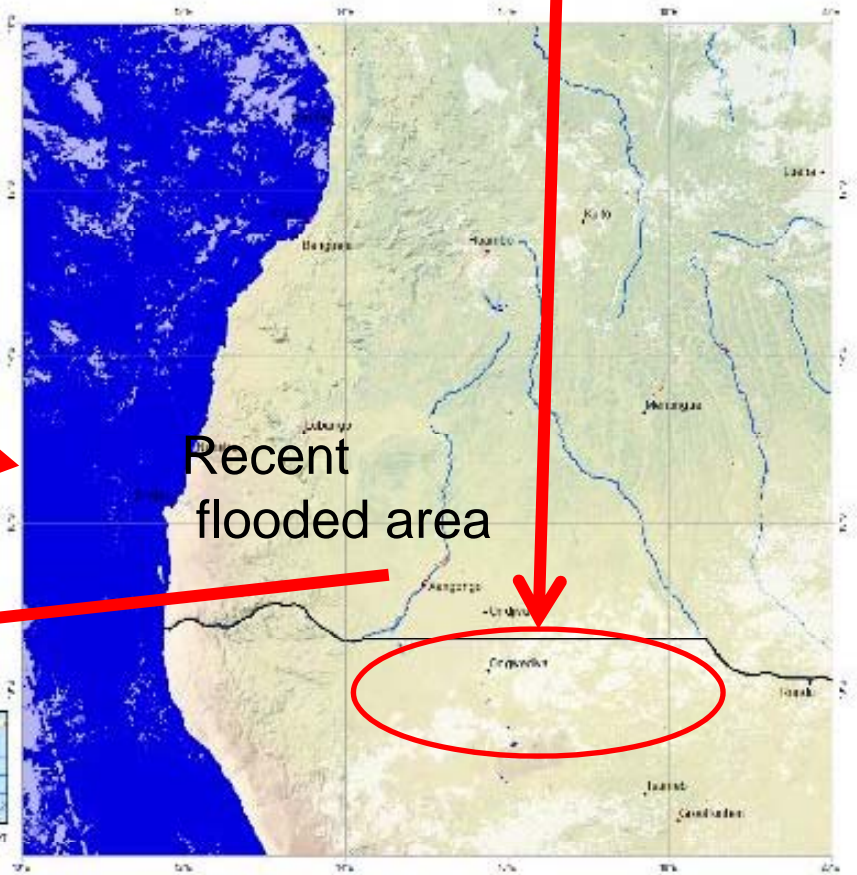
Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Area toured on January 2011 trip

NASA EXPERIMENTAL SCIENCE PRODUCT

MODIS Flood Map  
28-30 Jan 2011  
Tile: 010E010S

- Current floodwater (MODIS image)
- Cloud (MODIS image)
- Reference water (MODIS image)
- Urban areas
- Background (MODIS image)



Recent flooded area



# Sample of Planned Addition of Higher Resolution Flood Product Overlay Using EO-1

## EO-1 Land Cover Land Use Change

ALI Imagery of Australian Flood (Mar. 2009)



March 12, 2009  
True-Color Image  
EO-1 ALI Image

In this true-color image, note how the water color is so muddy that it makes discerning the extent of the flooding difficult.



March 12, 2009  
False-Color Image  
EO-1 ALI Flood Product

This false-color image combines infrared and visible light, which makes the extent of the flooding far more obvious. Water is dark blue, while plant-covered land is green, and bare earth is rosy tan.

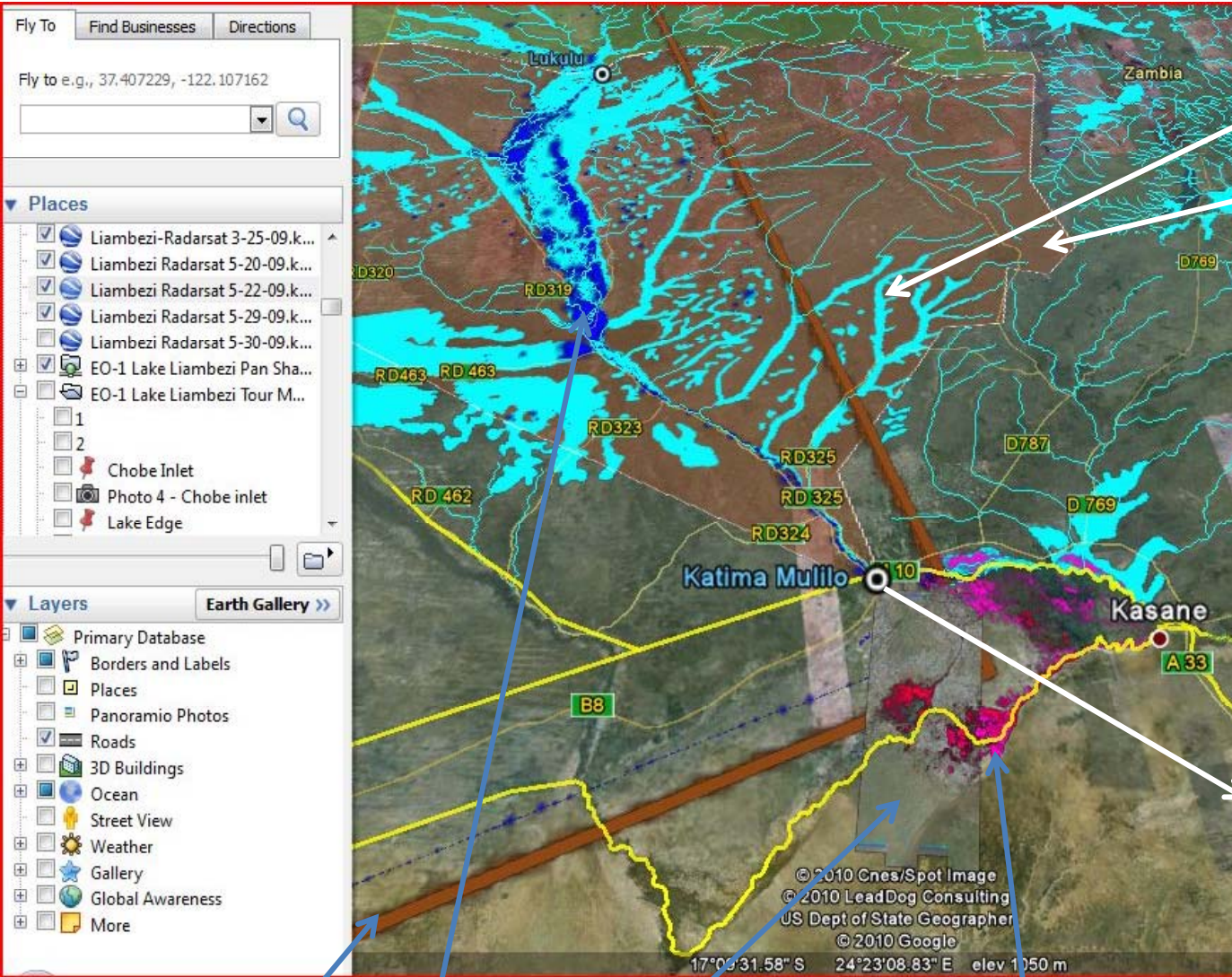


March 25, 2009  
False-Color Image  
EO-1 ALI Flood Product

Two weeks later, the flood waters have receded even more, which the EO-1 Flood Product makes evident.



# Mashup of Satellite Data and River Gauge Data Using Namibia2 (Google Earth Version) Webpage Tool



Zambia water lines from old database

Lower Zambezi catchment

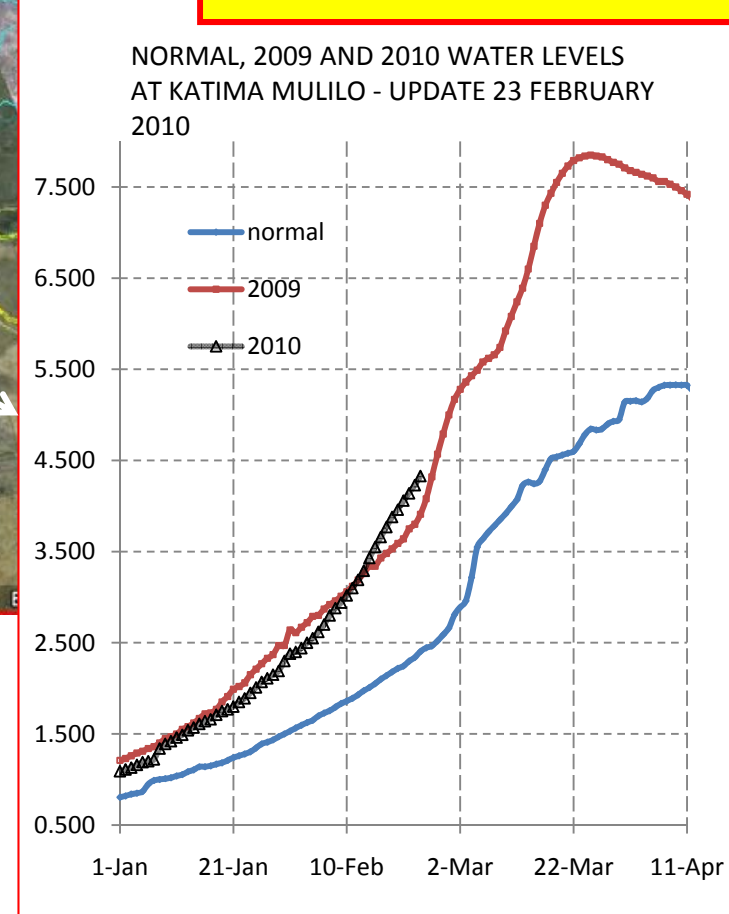
Multiyear river gauge measurements

Envisat swath

Envisat Data March 2009

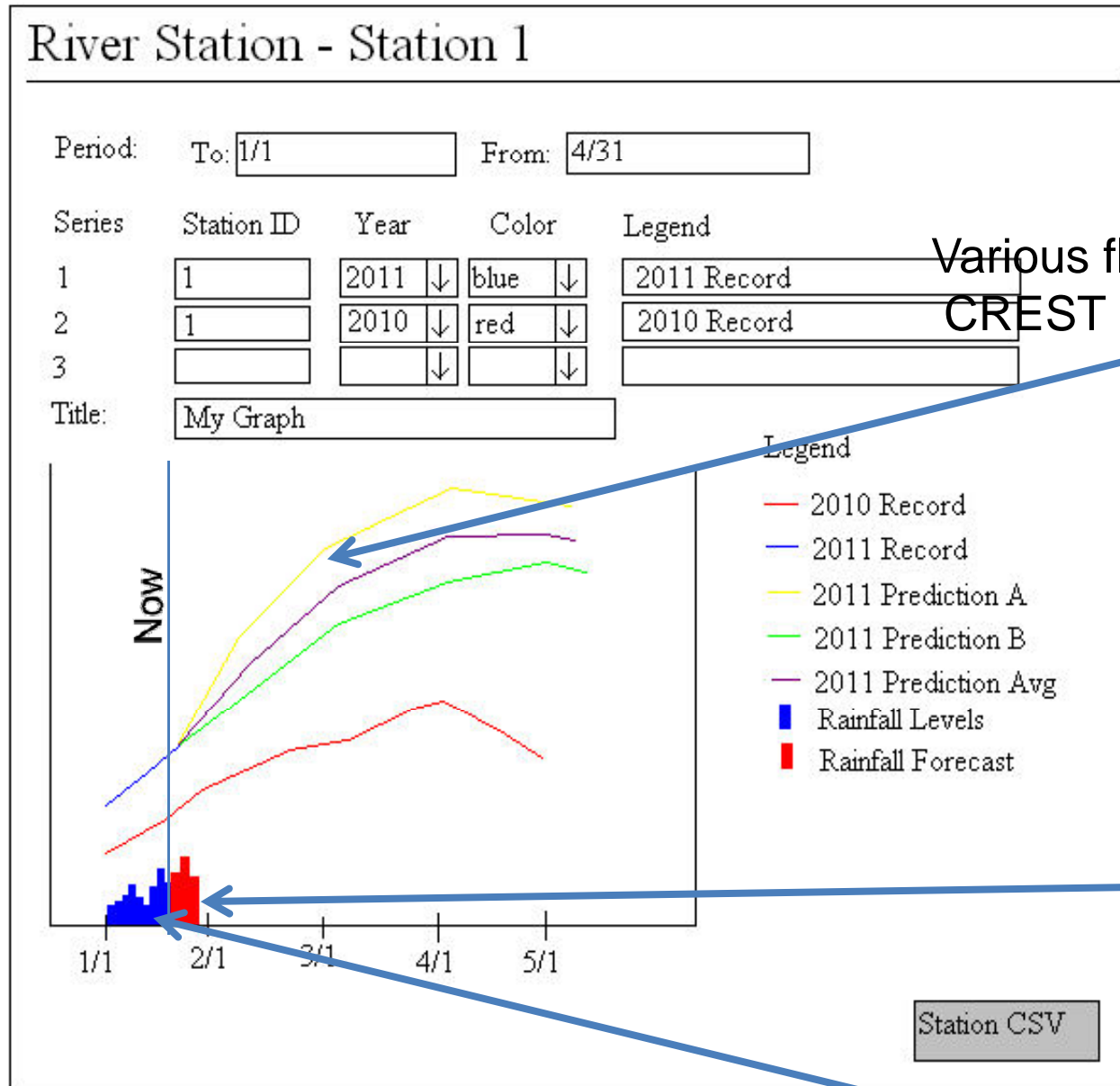
EO-1 Data March 2009

Radarsat Data March 25, 2009





# Mock up of Revised River Gauge Plot Page





Various flood models such as  
CREST model (Univ. of Oklahoma)

Rainfall prediction  
From GEOS-5

TRMM based daily  
rainfall estimates

# Sample Display of Multi-year Satellite Measurements (in month of March) of Katima Mulilo Linked to JRC Via Namibia Flood Mashup Based on Terra AMSR-E Microwave Instrument


**GDACS Global Flood Detection System - Version 2**



An experimental system to detect and map in near-real time major river floods based on daily passive microwave satellite observations. The purpose is to identify and measure floods with potential humanitarian consequences after they occur.

Home
Current floods
Global map
Search areas
Custom areas
Animations
Download
About

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### Create a customize graph by parameter

You can create a custom graph combining up to 4 time series. In a given time period, you can compare different sites (e.g. upstream, midstream, downstream for flood propagation) and/or different years (e.g. comparison with last year's floods). Available parameters are: flood signal (ratio of brightness temperature of observation and nearby dry pixel), flood magnitude (signal anomaly expressed as standard deviation removed from the mean) and estimated flooded area (in km<sup>2</sup>).


Area id:  Colour:  Legend:

Period: From  To

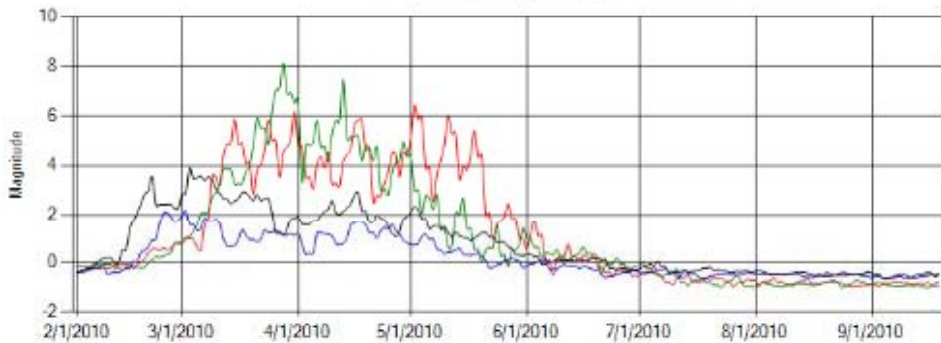
Series	Area id	Year	Colour	Legend
1.	<input type="text" value="14950"/>	<input type="text" value="2009"/>	<input type="text" value="Green"/>	<input type="text"/>
2.	<input type="text" value="14950"/>	<input type="text" value="2008"/>	<input type="text" value="Blue"/>	<input type="text"/>
3.	<input type="text" value="14950"/>	<input type="text" value="2007"/>	<input type="text" value="Black"/>	<input type="text"/>

Parameter:

Title:



**Katima Mulilo (DWAF) (14950) from 2010-02-01 to 2010-09-19**




- Magnitude in site 14950 for 2010
- Magnitude in site 14950 for 2009
- Magnitude in site 14950 for 2008
- Magnitude in site 14950 for 2007

[Download data](#)

Please note that the information provided on this website has no official status and does not replace local flood warnings. Please refer to the competent local hydrographic authorities for official information on the flood status in each country.

in collaboration with:



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# Sample Alert During Pilot

Namibia daily flood bulletin 03 March 2010:

There have again been heavy rains in parts of the Zambezi catchment. See attached NASA map. The waterlevels at Chavuma started rising again. See attached graph. Our forecast remains that the Katima Mulilo waterlevels are heading for 7 m by mid-March 2010. For perspective, the flood would be:

**similar to 2007**

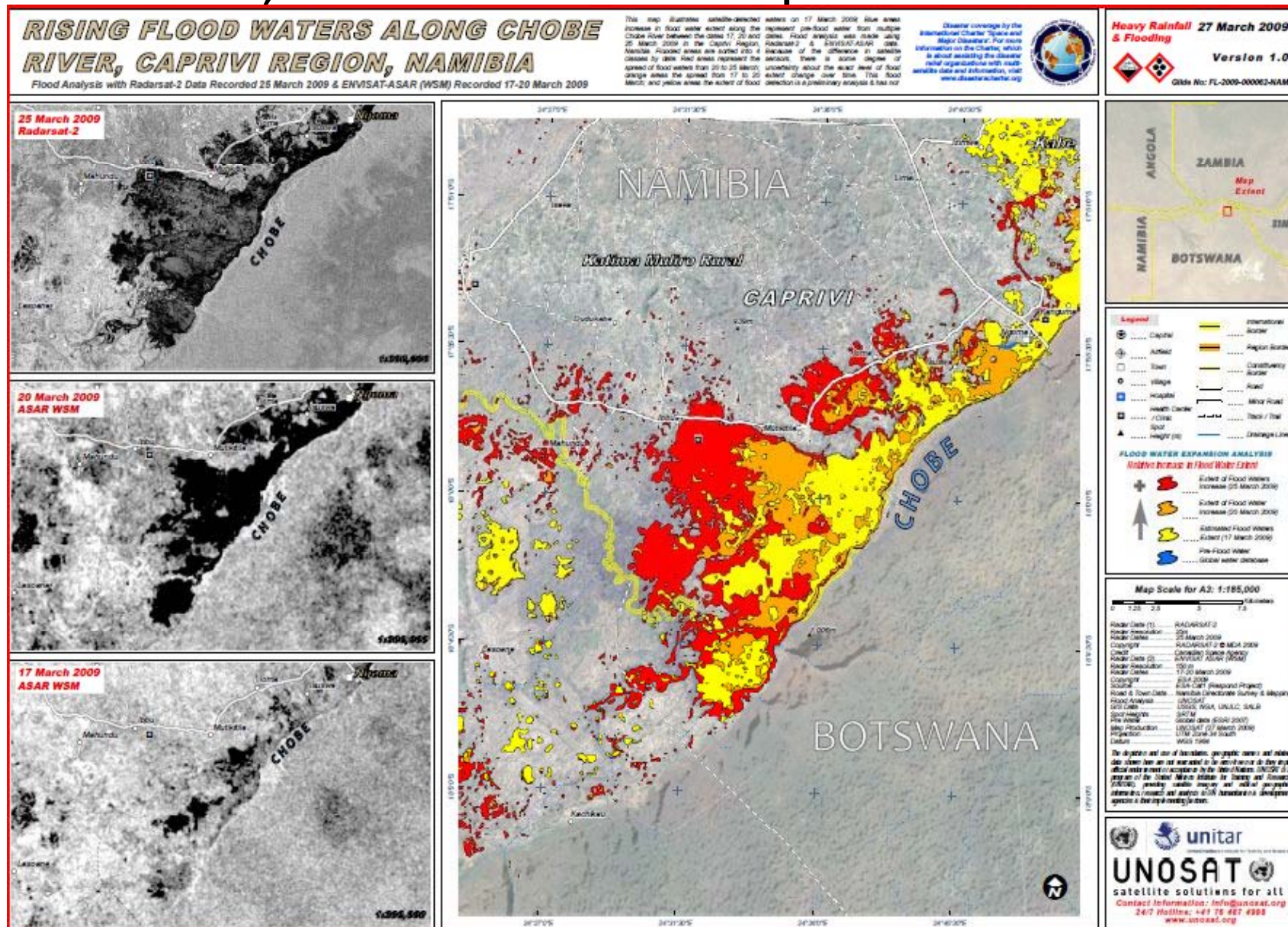
**higher than 2008**

**lower than 2009**

But much will depend on the rains and the catchment response in the coming weeks.



# Sample Time Sequence Flood Map Generated by Unosat, Derived from Multiple Satellite Data Sets



Vision is to generate similar product automatically when floods predicted and pair them with river gauge measurements

# Conclusion

- Combining Sensorwebs with an elastic computation cloud enables surge capacity for disasters by enabling parallel processing of various algorithms and other processes within the cloud
- Elastic cloud provides work space for user to customize their experience instead of a preset outputs